PRE-BOILOVER BURNING OF A SLICK OF OIL ON WATER

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ABSTRACT

The burning of oil in water is of great interest as a result of off-shore exploration, production and transportation of petroleum. This combustion phenomenon may constitute a hazard, i.e. and accidental burning slick drifting towards a platform, but it may also serve as a measure to minimize the environmental damage of an oil spill [1,2]. The available information on this phenomena is quite limited. Although great effort has been devoted to the understanding of pool fires [3] and flame spread over liquid pools [4] the specific issues related to a fuel burning over a water bed have deserved little attention. Most of the work being related to fires in fuel tanks and the phenomena commonly referred as "boilover" [5,6]. Only a few studies have dealt with the burning of a thin layer of fuel on a water bed. A good summary of existing knowledge is provided by Evans et al. [2].

The burning rate of a slick of oil on a water bed is calculated by a simple expression derived from a one-dimensional heat conduction equation. Heat feedback from the flame to the surface is assumed to be a constant fraction (χ) of the total energy released by the combustion reaction ($\dot{q}_S'' = 4\chi \dot{Q}/\pi d^2$). The total heat release, as a function of the pool diameter ($\dot{Q} = \rho_\infty C_p (T_\infty g (T_f - T_\infty))^{1/2} d^{5/2}$) is obtained from existing correlations [3,7]. It is assumed that radiative heat is absorbed close to the fuel surface, that conduction is the dominant mode of heat transfer in the liquid phase and that the fuel boiling temperature remains constant. By matching the characteristic thermal penetration length scale for the fuel/water system and an equivalent single layer system, a combined thermal diffusivity can be calculated ($\alpha_{EQ} = \dfrac{r y_{s,i}}{\alpha_F}(\sqrt{\alpha_w} + \sqrt{\alpha_F})^2$) and used to obtain a solution for the burning rate.

$$r = \frac{1}{H_v \rho_F}\left[\chi\left(\frac{4\,\rho_\infty\,C_p\,(T_\infty g (T_F - T_\infty))^{1/2}}{\pi}\right)d^{1/2} - \frac{\alpha_F \lambda_F (T_S - T_\infty)}{y_{s,i}(\sqrt{\alpha_F} + \sqrt{\alpha_w})^2}\right]$$

Theoretical expressions were correlated with experiments for crude oil (63% Kittiway, 33% Arabian Light and 4% Oural) and heating oil (a mixture of hydrocarbons ranging from C_{14} to C_{21}), for a number of pool diameters and initial fuel layer thickness [8] (figure 1). Experiments were also conducted with emulsified and weathered crude oil [9]. The simple analytical expression describes well the effects of pool diameter and initial fuel layer thickness permitting a better observation of the effects of weathering, emulsification and net heat feedback to the fuel surface. Experiments showed that only a small fraction of the heat released by the flame is retained by the fuel layer and water bed ($0.001 < \chi < 0.004$), that the effect of weathering on the burning rate decreases with the weathering period (figure 2) and that emulsification results in a linear decrease of the burning rate with water content (figure 3). Deviations from the predicted values arise from the assumptions used in the model and from the uncertainties in the experimental results for an initial fuel thickness smaller than 5 mm.

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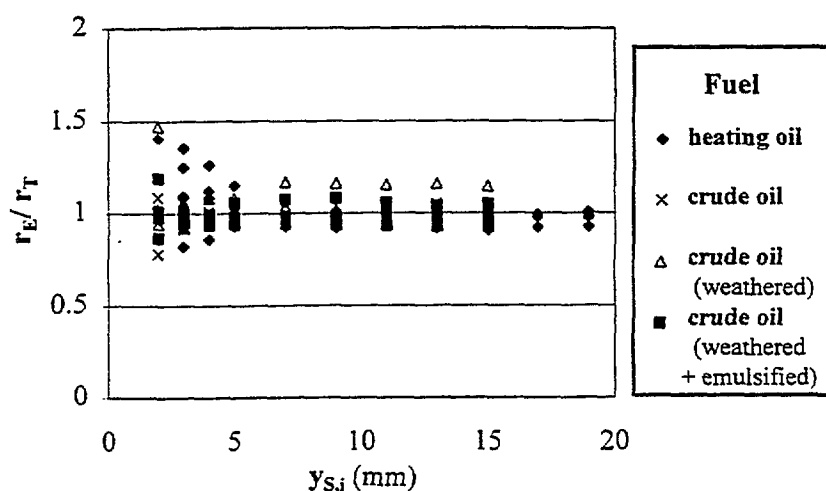
Figure 1. Comparison between experimental (r_E) and calculated (r_T) regression rates
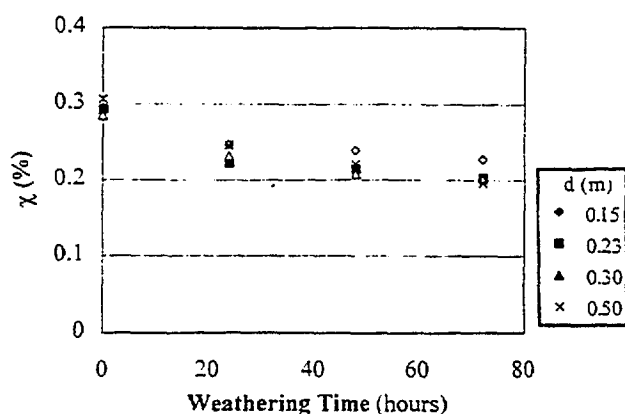

Figure 2. Efficiency constant as a function of the weathering period for crude oil
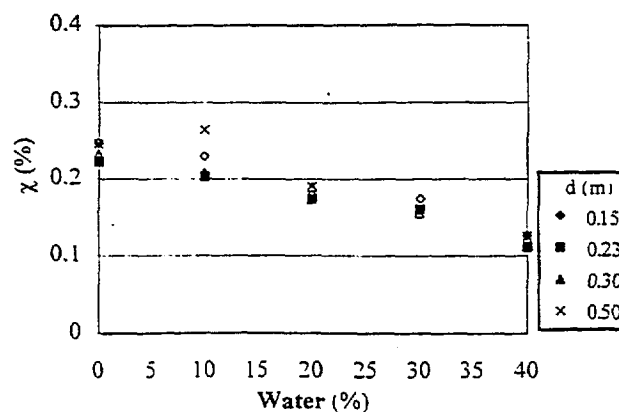

Figure 8. Efficiency constant as a function of water content period for emulsified crude oil (weathered 24 hours)